DREDGE-AND-FILL ACTIVITIES IN GALVESTON BAY

George H. Ward, Jr.

Center for Research in Water Resources
The University of Texas at Austin

Executive Summary

The primary early physical alterations to Galveston Bay, implemented in the last half of the Nineteenth Century, were the jettying of the main inlet and the development of the periphery of the upper bay, especially the Houston area and the region of the Trinity River. The direct effect of these was to stimulate navigation and shipping in the interior of the bay, which led to the need for channeling. In 1900, a federal channel of nominal 12-ft draft spanned Galveston Bay, from the Bolivar inlet between the jetties, across Red Fish Bar, through the cut at Morgans Point, and up Buffalo Bayou to the city of Houston at White Oak Bayou. Moreover, the deepening of the bar as a result of the improvements at Bolivar inlet allowed vessels drawing 25-ft to Galveston, which predictably motivated interest in a deep-draft (i.e., 25-ft) channel across the bay to Houston.

This deepdraft project was dredged in several stages, finally achieving 25 ft by 1915. This was the first in a succession of enlargements of the channel system. A new industry motivated the next channel expansion: the appearance of oil tankers in the world fleet after WW I. New project dimensions of 30 x 250 ft in Galveston Bay and 30 x 150 in the reach above Morgans Point were completed in 1926 (the bay reaches being completed in 1922). In the 1930's, the Houston Ship Channel was enlarged again, to 32 x 400 completed in 1937. Since WW II, there have been two additional increments in channel dimension. The first, beginning in 1949, is the enlargement of the Houston Ship Channel to a project depth of 36 ft. The next was the enlargement to a project depth of 40 ft, begun in 1963.

In close association with the development of the Houston Ship Channel was the creation of a channel to Texas City. The original, private 16-ft channel was assumed by the U.S. government, and included in the 25-ft channel network. This was completed in 1905, and extensive maintenance dredging was needed almost every year for the next decade. The Texas City Channel was laid nearly perpendicular across a natural scour channel known as Half Moon Channel. With sediment-laden currents regularly sweeping across Texas City Channel, the resulting high rate of siltation led to authorization of a timber pile dike along the north side of the channel, completed in 1915. This structure extended 28,200 ft out into Galveston Bay, and required 950,000 linear feet of timber pilings. In 1931-34 a rubble mound dike was constructed, creating the present Texas City Dike configuration.

Meanwhile, motivated by the Interstate Inland Waterway League, created in 1905, segments of a 5 x 40 ft inland canal were completed as a federal project by the Corps by 1909, including, in Galveston Bay, the old canal through Karankawa Reef from West Bay to the Brazos. The connection with the upper coast was finally completed in 1934 with the segment from East Bay to Sabine Lake. Also, the older strategy of running a canal from bay to bay was replaced with that of a landlocked channel paralleling the coast. This channel system, the Gulf Intracoastal Waterway, was enlarged to a 9 x 100-ft canal by 1942.

At present there are over 200 miles of federal channels in Galveston Bay (exclusive of the harbor channels). This includes 73 miles of deep channels (depths exceeding 36 ft), 76 miles of 12- to 15-ft channels, and well over 60 miles of channels of depth less than 12 ft. In terms of bay area, these channels occupy some 6300 acres, of which 80% is deep-draft.

The problem of siltation ("deterioration") of dredged channels crossing the open bay was confronted since the 12-ft Galveston Bay Channel of the last century. This was obviously related to silt-loaded currents crossing the channel, so an equally obvious solution was to protect the channel by a structure on the upcurrent side. This approach led to the construction of two extensive dikes in the open waters of Galveston Bay. One, the Texas City Dike, was described above. The second, part of the 25-ft project for the Galveston Bay Channel, was a 60,000 ft dike of timber pilings and brush extending from Morgans Point south along the eastern side of the channel. The dike was completed in 1902, but was plagued with deterioration due to the harsh environment. The storm of 1911 destroyed all but the uppermost 7,500 ft. However, the spoil bank here, Atkinson Island, had now stabilized to continue to provide the same protective function as the old dike.

Most of the channel projects in the interior of the Bay have been dredged under contract to the USCE. Each contract is preceded by a Before-Dredging survey, and upon completion of the work, is followed by an After-Dredging survey. Their difference for each sub-reach of the contract gives the volume of material removed, upon which payment is based. Data on dredged volumes for contract subreaches were made available to this study by the USCE Fort Point Area Office, all of which was keyboarded from Corps records, referenced to a uniform positioning system and accumulated by standard lengths along the channel projects. It was then further aggregated in time and space for analysis. Depictions of dredging in each of the principal channels are presented by 5000-ft sections, by major reaches and by channel project, annually since 1945. This analysis distinguished new work, involving the excavation of virgin material, from maintenance, in which the channel is restored to its project dimension.

Maintenance dredging, in contrast to new work, is presumably more closely related to physical processes of resuspension and siltation. Despite the high year-to-year variability of dredging in the individual projects, on a bay wide basis the annual maintenance volume is more consistent at about 8.5 x 10^6 cu yds since WW II. Moreover, the rate of maintenance dredging has been reduced by about 40% over the past three decades, a reduction dominated by the confined reach of the Houston Ship Channel and the reach above Red Fish Bar. In the lower bay,

the 30,000-ft reach from the Entrance to above the end of Texas City Dike has required practically no maintenance dredging in the past 50 years. This reach transects the zone of convergence of flows into and out of the estuary, a zone which is naturally scoured and therefore exhibits some of the highest natural depths in Galveston Bay. It appears that the higher currents in this zone prevent accumulation of silt in the channel.

Prior to WW II, dredged material from projects within the interior of the bay requiring open-water disposal was freely sidecast, usually at the convenience of the dredger. Although the problem of re-dredging the same material was clearly recognized by the Corps, the economics of pipeline operation, especially in the open bay, did not offer alternatives. Since the 1960's (earlier in some areas of the bay), specific regions have been designated as disposal areas. As dredged material has accumulated, these regions have become shoal and even emergent. Some have been stabilized around their periphery by levees, and the strategy is to ultimately levee all open-water areas. While the recordkeeping on disposal of dredged material is not nearly as detailed as that for removal of dredged material, for the purposes of this project, the important action is the creation of the disposal area. From the standpoint of Galveston Bay, that area is essentially isolated and removed from the bay system. All told, there are about 27,000 acres of such designated disposal area in the Galveston Bay system. Open-water sites, i.e., those sites that now displace what was previously open water, total about 19,500 acres.

There is a considerable range of dredge-and-fill operations not carried out by the Corps of Engineers, but rather by private interests and public agencies. These include port approaches and dock facilities, marinas and boat slips, drilling and well installation, pipelines, canals and channels, bridges and shoreface structures, bulkheads, revetment, dikes and levees, borrow excavations, land filling and grade elevation, and outfall structures. These and related activities are regulated through the approval and issuance of Department of the Army (DOA) permits, colloquially referred to as "404 permits." Almost any physical modification to a watercourse or its adjacent wetlands now requires a DOA permit. Galveston District USCE has a considerable body of records documenting this permitting activity, in the form of microfiche copies of file records on permits. The permitting traffic is immense, totalling 4,245 separate permits for 1940 through 1991 for the Galveston Bay area, averaging about 100 per year since 1950.

Galveston District made available to this project all of its file holdings on DOA permitting. In view of the large number of permits and the sheer bulk of the material on file for each permit, a two-pass approach to data compilation was employed. Pass One entailed a comprehensive inventory of all permits issued by the Corps for the Galveston Bay system, including date and number of permit, general location of the project (i.e., county and watercourse), and character of the work in one or several categories. Pass Two comprised a quasi-statistical subsampling, focusing upon those permits for work within or immediately adjacent to Galveston Bay, including the lower reaches of tributaries flowing directly into Galveston Bay or a principal subsystem of the bay, and involving specifically dredge or fill activities. The permit files were examined in detail to

determine quantitative data on location (as latitude/longitude), volume and area of affected areas, and types of habitat displaced or created.

There is a major impediment to applying 404 permit data directly to the objectives of this study. A 404 *permit* is simply that: a license to carry out certain physical modifications bound by the parameters of the permit. Many permitted projects are never implemented, or are implemented on a scale smaller than allowed in the permit. Some are "blanket" and general permits, allowing certain generic operations within large areas of the bay, under which any number of actual activities can be performed. Permits for oil and gas wells are typically awarded on a general basis. There is no information on which permitted projects are or are not actually implemented (apart from the negligibly rare District inspection reports), nor on the quantitative dimensions and numbers of the work performed. Data compiled by the Atlantic Marine Center of the National Ocean Service on status of 404-permitted projects that could impact navigation were analyzed: for the entire Atlantic seaboard, including the Texas coast, the rate of completion is about 30%. Therefore, the quality of the information is much poorer for 404 activities than for federal dredge-and-fill work, and the magnitudes of such work could only be estimated in this study.

Cumulatively since WW II, we estimate that 404-permitted projects have dredged 64 x 10^6 cu yds from nearly 3000 acres, both maintenance and new work, in the Galveston Bay system. This is secondary to the federal channel projects, which have removed cumulatively since 1900 about 260 x 10^6 cu yds and since WW II 81 x 10^6 cu yds of new work, 80% of which is in the Houston Ship Channel. Federal maintenance dredging has removed 650 x 10^6 cu yds since 1900 and 401 x 10^6 cu yds since WW II. On the other hand, the 404-permitted work tends to be concentrated in the nearshore zone, while the federal projects tend to be in open-water areas.

Broad trends in the time history of DOA permitting for the general region of Galveston Bay appear to be governed by regulatory and economic factors. After WW II, the rate of permit issuance rose to about 70 per year, which was maintained, more or less, from the late 1950's to the early 1970's. Then, the rate of permits rose precipitously to about 180/yr by 1976. This is indubitably a response to the new 404 requirements of FWPCA (PL 92-500), and the formalization of the 404 process, but also due to economic expansion during this period. Beginning in the early 1980's the rate of permitting began to drop, ultimately by the late 1980's to a level on the order of that prior to promulgation of FWPCA regulations. This drop is probably driven by economics, a reaction to the sequence of economic calamities that have been visited upon the region since 1980, including the collapse of the oil market and its direct impact on offshore production, the southwest real-estate bust, and two nationwide recessions.

As a function of position in the bay, 404 activity tracks intensity of development, as might be expected, the Houston Ship Channel (including the side bays and the San Jacinto River) having the single highest density of permitting in the system. Moreover, the upper Houston Ship Channel, Galveston Channel, Texas City Channel and Clear Lake together account for about one-half of the permits issued

for the entire system. There is a coherence in the time signal of 404 permitting in the different subregions of the bay, which suggests that 404 activity in Galveston Bay is partially driven by a factor(s) that is uniformly exerted over the entire region. Economics would clearly be one such factor.

Various analyses of the above data are presented, including spatial and temporal variation in various categories of activity. Other types of dredge-and-fill activity are considered as well. Most important of these is shell dredging. Although shell dredging in Galveston Bay was terminated nearly 25 years ago, great volumes of reef shell were removed from the bay up until that time. We estimate that a cumulative volume of 220 x 10^6 cu yds of shell was taken from Galveston Bay from 1910 to 1969.

The impacts of dredging and filling on habitat are evaluated from several standpoints. In terms of gross physiographic alteration, the volume of the bay has been incremented 30% since 1900 by various activities and processes. The principal contributors and their relative effect, as a *percentage* of total bay volume, are:

Subsidence:	+ 36
Siltation:	- 14
Dredged material disposal & fill:	- 8.5
Deepdraft (>36 ft) channels:	+ 6
Shell dredging:	+ 6
Other dredging & shallow draft channels:	+ 2.5
Isolation:	- 1

"Isolation" refers to the removal from the estuarine system by imposition of a barrier. Some projects can influence a section of the bay much larger than their physical dimensions. Because the size of dredge-and-fill activities was based upon the dimensions of the actual construction, a separate accounting was necessary of those few projects that impound or isolate larger sections of the bay. (The closure of Turtle Bay to form Lake Anahuac is a prominent example.) From this volume budget, it is apparent that subsidence is the single greatest factor driving physiographic modification on a baywide basis. However, the spatial distribution of these processes must be considered also. Dredge-and-fill projects in particular tend to be concentrated in specific areas, rather than spread uniformly over the bay.

This study adopted the viewpoint that a dredging or a filling activity replaces one habitat with another. For example, dredging a channel through a shallow bay replaces shallow bay habitat with non-shallow. Disposal of the material in the open-bay can effectively replace bay habitat with shallow-water, or upland if the material becomes emergent. Habitat categories were morphologically based, e.g. pre-altered, bay-bottom, shallow bay-bottom, marsh, oyster reef. About 2.5% of the surface area of the bay is dredged. The dominant type of filling work is, by far, dredged material disposal. Of the open bay area, 6% has been used for disposal, most of which is designated disposal areas, primarily--but not exclusively--used for federal projects. The 404-permitted dredging activities are more significant on

an areal basis than a volumetric (since these projects tend to be shoal draft), comprising about one-third of the total dredged area of the bay. Moreover, these projects tend to be more concentrated in the shoreline, nearshore and shallow-bay areas than the federal projects.

Shallow bay bottom (depths less than 5 ft) comprises about 40% of the bay open-water area. The cumulative loss of shallow bay habitat through dredging, both federal and non-federal, is about 1% of the total baywide shallow water habitat, and through disposal about 5% baywide. The net gain due to subsidence, about 8%, more than compensates for this loss. Isolation is responsible for an additional loss of 6% of shallow bay bottom.

The relative impact of dredging and filling on marshes is more difficult to quantify due to lack of a good early-century baseline. Using the photogrammetric analyses of White et al. (1992) for the 1950's marsh distributions as a baseline, dredging, filling and disposal in marshes has eliminated 5%, of which 2% is due to designated disposal areas (42% of which is in East Bay and 49% in West Bay), 0.5% acres to navigation channels and the remainder to 404-permitted activities. Mitigation has restored or created some, but is negligible on a baywide scale. Overall, there has been a net loss of about 9% of the (1950's) marsh area, about half due to subsidence and half to dredge-and-fill activities. Isolation is responsible for removing an additional 10% of the estuarine marsh area, the biggest single decrement being due to closure of Turtle Bay in 1936.

Much of the 404-permitted activities are concentrated in the nearshore or shoreline regions, and therefore may have a disproportionate impact on this fringe habitat. Bulkheading alone is estimated to have impacted at least 6% of the shoreline of the bay. Dock construction and revetment have altered probably another 4%.

In addition to direct impact on habitats, these physiographic modifications are capable of influencing the hydrography and circulation of the bay, and indirectly its water quality. The separation of these type of impacts in the complex hydrodynamic behavior of Galveston Bay is difficult, and no thorough quantitative study has been done. Probable impacts include augmentation of the tidal prism by enlargement of the entrance, construction of deep channels and general deepening of the bay, alteration of internal circulation by barriers such as Texas City Dike and the line of disposal areas along the bay reach of the Houston Ship Channel, and enhanced density currents and salinity intrusion in the deep channels.